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Applying remote sensing and GIS on monitoring and measuring urban sprawl. A case study of China

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Summary

The understanding on urban sprawl in China still rest on qualitative discussion instead of quantitative analysis. There is no clear answer to identify and evaluate the extent of sprawl. The existing methods for measuring urban sprawl are mainly put forward within the context of Western developed countries. To find good ways for analyzing the spatial features and unique mechanism of urban sprawl within Chinese context is very important .On this background, the techniques of Remote Sensing and Geographical Information System (GIS) to monitor and measure urban sprawl are described in this paper. The built–up areas were obtained from the Landsat TM classified images of four different periods to monitor the dynamic changes of urban sprawl. Choosing the different indicators and measuring the urban sprawl use these indicators based on GIS, on the basis of the calculation results of comprehensive indicators, the sprawl features of research area were identified.

Key words: Urban sprawl; Remote Sensing; GIS; Monitor; Measure

1 Introduction

Urban Sprawl is a major problem in the course of the urban development of the Western countries in the 20th century, most of the urban sprawl is considered to be the expansion of low-density accompanied by a series of environmental and socio-economic issues.

Across states and cities of Europe and North America there is a growing awareness of, and concern about urban sprawl, which has different background from the cities of China. The cities of China have been developing rapidly after reform and opening-up since 1980, urban sprawl has emerged in some regions. Land development has been out of control and the construction land has kept expanding blindly, especially in the marginal areas of some metropolises.

Some experts pointed out: the phenomenon of urban sprawl in the past decades is extremely severe, and the tendency of scattered development and sprawling growth has been formed, which will seriously impede the modernization process in China if it could not be controlled. In China, some human geography and sociology scholars regarded urban sprawl as a by-product of suburbanization; some physical geography scholars described the process of urban expansion using remote sensing and tried to forecast the trend of urban expansion, but no good explanation of urban sprawl raised up; some planning scholars characterized qualitatively urban expansion and pointed out the problems of urban sprawl during the process of urban expansion, and they gave some planning measures to solve these problems ,but the inner mechanism of urban sprawl was still no clear expression. There are just few studies on how to measure urban sprawl (Anthony Gar-On Yeh, Xia Li 2001), (Jiang Fang et al 2007), (Jingnan Huanget al. 2007), (Li, Y. a. X. 2001). In short, the research on urban sprawl in China is still in a preliminary stage, the basic characteristics of urban sprawl in China have no explicit expression, and the reveal of its internal mechanisms has been maintained in the level of empiricism.

How to measure urban sprawl has been a hot spot of research. Some research organizations have put forward their indicators for measuring urban sprawl. Besides, many scholars focus on using indicators to measure urban sprawl by establishing multi-dimensional indicators by GIS analysis or descriptive statistical analysis (Ewing, R. P., Don Chen. 2002), (Frenkel, M. A. 2005), (Galster, G. et al. 2001), (Kent B. Barnes et al. 2001), (S.Fina, S.Siedentop. 2008), (Song Y, G.-J. Knaap. 2004), (Schneider A, C. E. W. 2008), (Tsai, Y.-H. 2005). Remote sensing and GIS can be separately or in combination for application in studies of urban sprawl. There are some researches on how to use remote sensing and GIS to monitor and measure urban sprawl (Anthony Gar-On Yeh, Xia Li. 2001), (H. S.Sudhira at al. 2004), (Jingnan Huanget al.. 2007), (Li, Y. a. X. 2001), (Mahesh Kumar Jat et al. 2008), (Neelakantan .K, S. Kulkarni a. V. Raghavaswatmy 2007), (Wei Ji, J. M. et al. 2006), (Xi Jun Yu, C. N. Ng. 2007).

In this research, an attempt has been made to find a good way to monitor and measure urban sprawl. I used the multi-temporal Landsat TM images to carry out the image classification. The built-up areas of four different years were extracted from the classified images so that the dynamic changes and the characteristics of urban sprawl could be recognized, and then the built-up area was regarded as one of indicators. Together with other different indicators, I constructed the indicator system to measure urban sprawl. The calculation of indicators was carried out based on GIS, the final results of analysis were visualized as maps. On the basis of the calculation results of comprehensive indicators, I identified the different level of sprawl in Jiangning County.

2 Research Area and Data

2.1 Research area

Jiangning County is situated in the middle part of Nanjing City, the capital of Jiangsu Province,

southern band of Yangtze River with the geographic location 118°30′~119°25′E and 31°30′~32°00′N (Figure 1). Jiangning County is located in the basin of Qinhuai River which is a tributary of the Yangtze River. Jiangning County presides 2 towns and 7 neighborhoods, the population is 845,500 in 2006, and the total area is 1, 567 km².

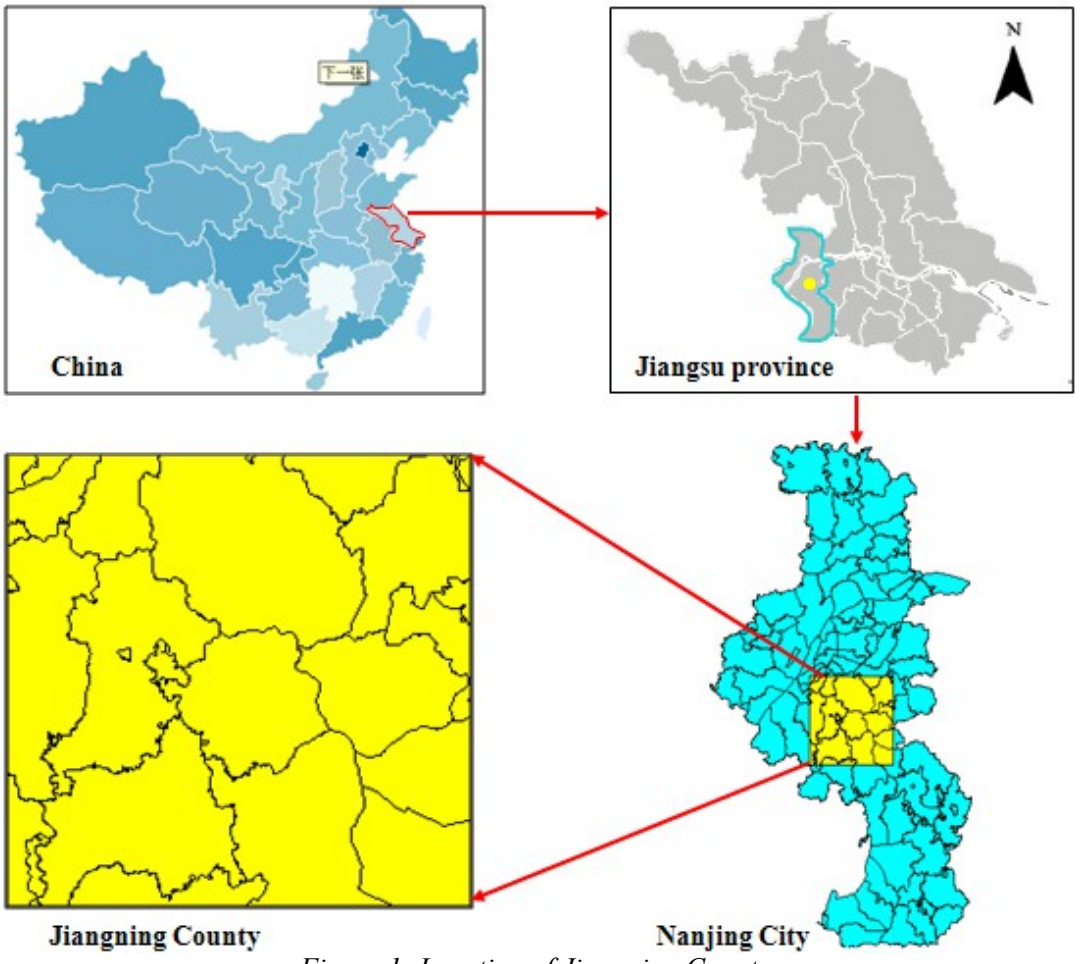

Figure 1: Location of Jiangning County

Before 1980, Jiangning County was a traditional agriculture area, and in fact it was an important grain supply base for Nanjing City. Rapid growth of rural enterprises in Jiangning County started in 1980, the construction of economic and technical development zones accompanied by improved transportation facilities have resulted in remarkable changes in economic activities and in pattern of land use (Ju Jingsha 1998). These activities led to loss of most fertile cultivated lands and the problem of urban sprawl.

2.2 Data source

Name	Spatial Resolution (m)	Assess Time
Remote Sensing Landsat TM Data	30 m	1979.08.06 1988.07.05 1998.10.18 2003.07.31
Demographic data		1980-2007

Table 1. Data source of research

3 Methodology of research

3.1 Remote sensing image classification

The technique of remote sensing provide a powerful tool for studying urban issues, like land use/cover change, urban growth modelling, urban sprawl etc. Remote sensing image classification is one of important application aspects for remote sensing technique, through computer processing with specific software like ERDAS, the results of the classification of land uses can be auto-outputted. In this research, I used the multi-temporal Landsat TM images which covered whole Nanjing city to carry out the image classification. The traditional information extraction from remote sensing image is mainly based on spectral respond feature, so the classification accuracy was not high because of the mixed pixels. Besides the spectral respond feature of remote sensing image, I considered the other features like geographic feature, principle

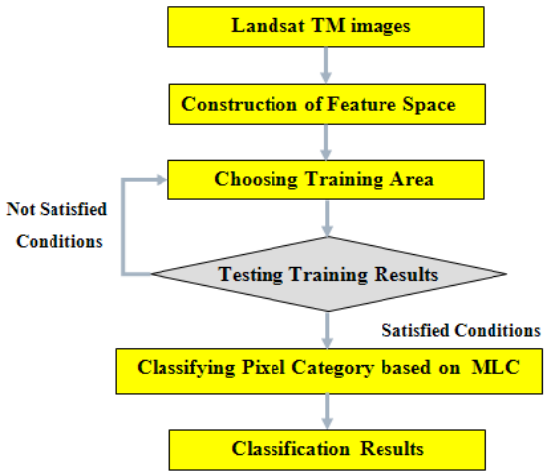

Figure 2. The process of image classification

component feature. The method of Maximum Likelihood Classification was used to classify the different land uses, and then built-up areas were recognized and extracted from the classified images (Figure 2).

3.2 Built-up area extraction

The built–up areas of four years were extracted from the classified images, from which we can know the dynamic changes of urban sprawl in Jiangning County. For the Landsat TM images, the built-up areas were extracted after image pre-processing and image classification, and then built-up areas were regarded as one of the indicators to measure urban sprawl. The sketch shown in Figure3.

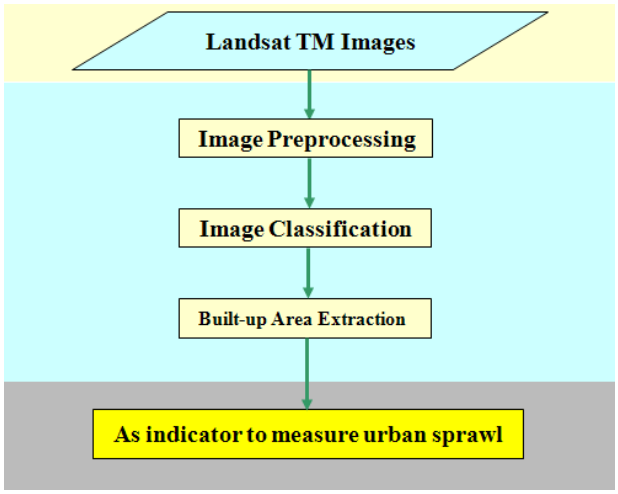

Figure 3. The technique sketch of built-up area extraction

3.3 Indicators construction and GIS spatial analysis

Urban sprawl has a variety of different patterns like fragmentation, leapfrogging, discontinuous development etc. For urban sprawl, a clear and unique dixtinction requires justified rules in weighing up several components and indicators. In order to scientifically measure the extent of urban sprawl, many scholars and research institutions presented their “Sprawl index”, which could exactly reflect the sprawling situation of a whole city or region (Jiang Fang et al. 2007), but they are not suitable very much for mearuring sprawl in China.

As for China, some indicators developed for urban expansion reflecting spatial features such as density of built-up area, intensity of annual growth; reflecting growth scale such as the area or share of urban growth, reflecting growth speed such as annual growth rate, elasticity of urban growth to population, and reflecting landscape configuration such as shape index, fractural dimension, isolation etc. (Jiang Fang et al. 2007). But how to use indicators to measure urban sprawl in chinese context is still a challenge.

Considering the built-up area as a potential and fairly accurate parameter of urban sprawl, built-

up area was taken as an important indicator of measuring urban sprawl (H. S.Sudhira, T. et al. 2004). According to the research result of Prof. Siedentop and Fina, three different types of indicators can be used to measure urban sprawl, including density, pattern and surface indicators (Figure 4), which cover the different dimensions of sprawl corresponding with environmental, social and economic impacts of urban land use change (S.Fina, S.Siedento 2008). In this result, surface indicators are focused on the quantitative composition of land use regarding features of land cover; Pattern indicators depict distributional aspects of urban entities; Sprawl-type developments contribute to declining urban densities so that density is a very important indicator.

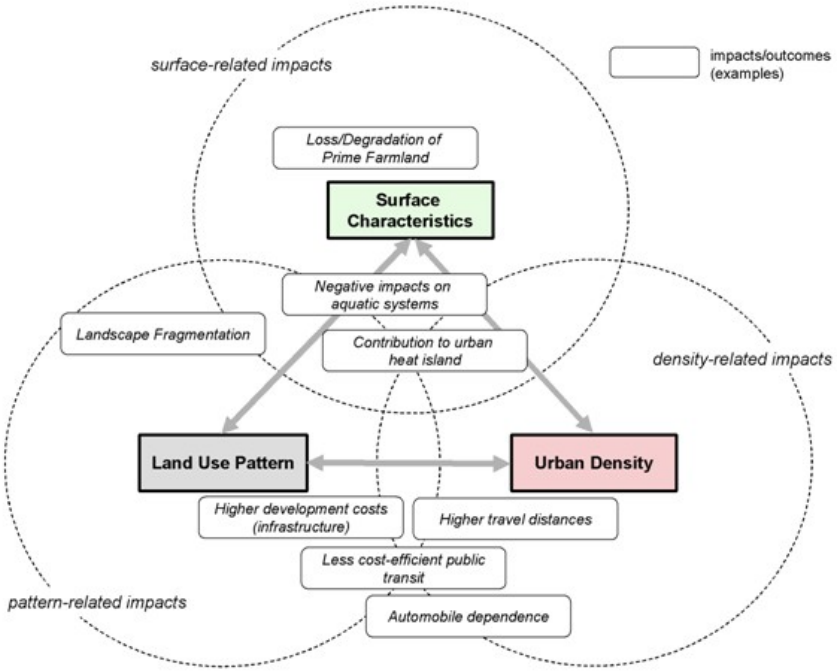

Figure 4: Impact phenomena caused by changes of land cover, land use pattern and density (From Prof.Siedentop and Fina, 2008)

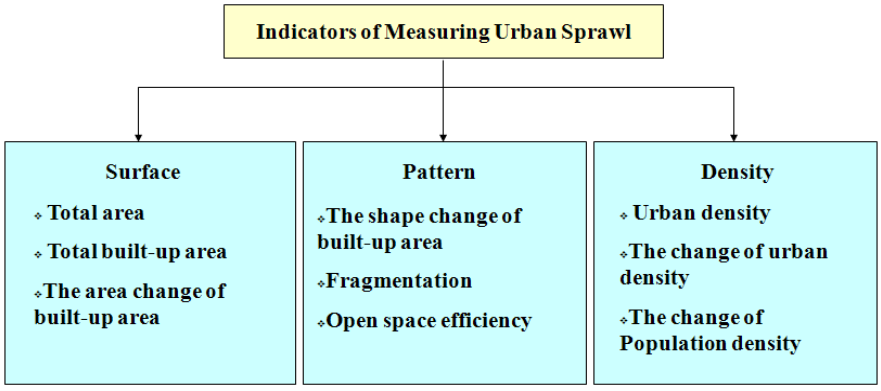

Figure 5: Indicators for measuring urban sprawl in Jiangning County

According to this result, I constructed the indicator system to measure urban sprawl in Jiangning County with the specific situation of the research area (Figure 5). Surface indicators include total area, total built-up area and new consumption. Pattern indicators include the shape change of built-up area, fragmentation and open space efficiency. Density indicators include suburban density, the change of suburban density and the change of population density.

4 Results and discussion

Three types of land use including built-up area, water area and other areas were obtained from four period classified images (Figure 6). We can see the big changes of built-up area in different periods. In the north part of research area, there is a very significant change because economic and technological development zone was built. In the south part, the new airport was used on 1 July 1997.

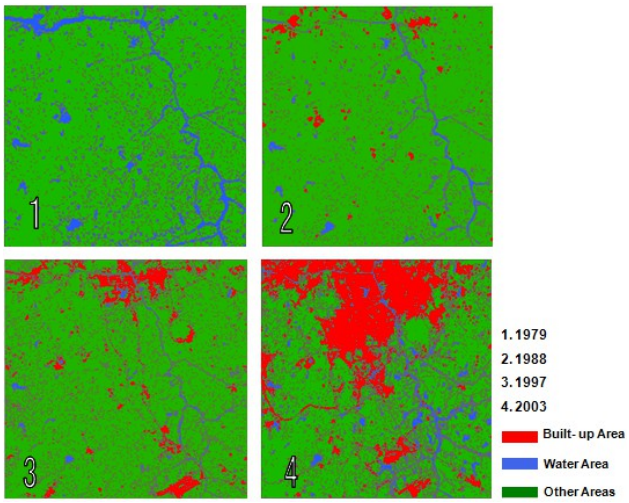

Figure 6: The classified images of research area

Galster *et al*., 2001, have classified sprawl into linear development, development by jumping on the green area, continuous but dispersed development and other different ways on the basis of their level of compactness or sprawling (Figure 7).

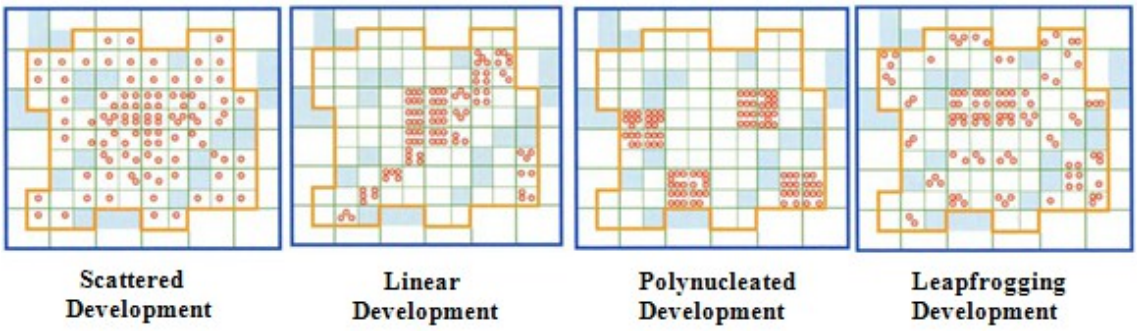

Figure 7: Physical patterns defining sprawl (From Galster et al. , 2001)

From the classified images, we can see the basic characteristics of urban sprawl in Jiangning County. Three sprawling patterns are identified: randomly expansion at urban fringe, scattered development of industrial land and leapfrog development of urban residential area (Figure 8).

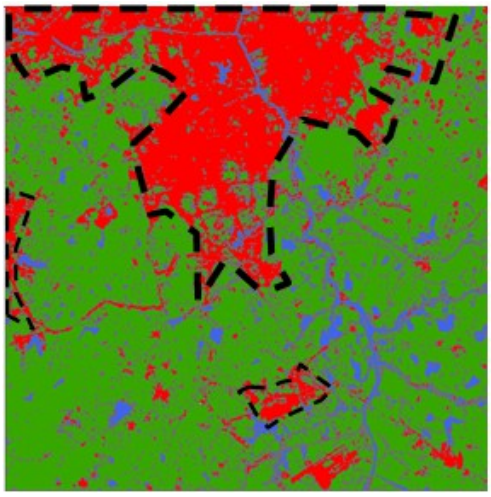

Figure 8. Physical patterns of Sprawl in Jiangning Country

On the basis of the indicator system, the situation of urban sprawl in research area was implemented based on GIS. The urbanization of Jiangning County has a big change from 1990 which impact on urban sprawl very seriously. According to the result of total area and total built-up area, non-agricultural land is one of the strong evidence for discontinuous development and leapfrog development. Urban sprawl has brought significant effects on agriculture, environment and city life. Firstly, urban sprawl has led to huge loss of high quality arable lands in the suburbs. Secondly, urban sprawl has encroached upon limited open space, such as forests, grassland and water area. Thirdly, the urban sprawl caused traffic burden increases the distance between the

newly developed land and city centers where job opportunities concentrate upon. I classified into three categories of the newly development land with integrated urban sprawl indicators: low sprawling, moderate sprawling and high sprawling (Figure 9).The result showed that sprawling amount in the northern part is larger than that of the southern, but the sprawling extent is in converse case. Besides, severer sprawling mainly concentrates in the marginal area of the near suburbs.

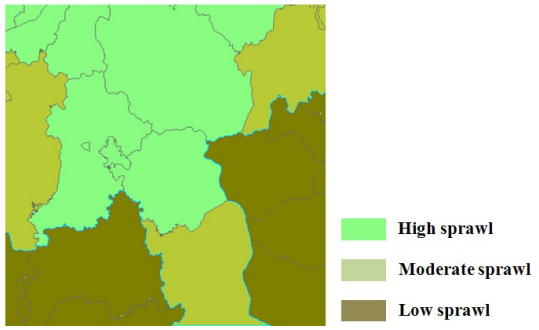

Figure 9: Three categories of sprawl in research area

5 Conclusions

The analysis result showed that non-agricultural land in Jiangning County has kept fast growing with large amount, low efficiency and disordered spatial configuration, indicating a typical sprawling tendency. The following specific sprawl features are identified: obvious fragmentation and irregularity of landscape due to unsuccessful enforcement of land use planning; unadvisable pattern of land use growth with typical discontinuous development, strip development and leapfrog development; low density of land use growth, low population density; and other negative impacts on agriculture, environment and city life. The application result indicates that the indicator system can capture most of the sprawl features and interior differentia as well. These indicators cover different dimensions for measuring urban sprawl. Some indicators could directly depict the microcosmic features; some indicators could indicate the growth pattern; some indicators on growth efficiency are more dependent on the precision of spatializing process. Due to the limitation of data, the indicator system is not very well to measure urban sprawl, so it must be improved in the future.

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